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16. ABSTRACT The paper describes EPA work in several areas relating to reducing SO ₂ and NO _x emissions from coal-fired utility boilers, and provides an overview of objectives, approach, current status, and plans for each. In addition, it describes plans for a small-scale selective catalytic reduction (SCR) system. SO ₂ and NO _x are major pollutants resulting from fuel combustion. Coal-fired utility boilers account for about 65% of the SO ₂ and 29% of the NO _x emissions in the U. S. These pollutants are generally believed to be major precursors of acid rain, and their control is a significant concern of the U. S. EPA, the utility industry, and other private and public organizations. The national strategy for reducing acid rain is still being debated in Congress; the choice of a strategy will determine the control techniques for limiting SO ₂ and NO _x emissions from utility boilers and will most likely include a mix of technologies to achieve the desired reduction at minimum cost. ←			
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SO₂ AND NO_x CONTROL TECHNOLOGY
RESEARCH, DEVELOPMENT, AND DEMONSTRATION

RICHARD D. STERN
CHARLES B. SEDMAN
FRANK T. PRINCIOTTA
AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA

INTRODUCTION

Sulfur dioxide and nitrogen oxides, SO₂ and NO_x, are two major pollutants resulting from fuel combustion. Coal-fired utility boilers account for about 65% of the SO₂ and 29% of the NO_x emissions in the United States.¹ These two pollutants are generally believed to be major precursors of acid rain and their control is a significant concern of the U. S. Environmental Protection Agency (EPA), the utility industry, and other private and public organizations.

The national strategy for reducing acid rain is still being debated in Congress; the choice of a strategy will determine the control techniques for limiting SO₂ and NO_x emissions from utility boilers and will most likely include a mix of technologies to achieve the desired reduction at minimum cost. Of the existing commercial control options, flue gas desulfurization (FGD) is costly, and switching to a lower sulfur content fuel may have severe socioeconomic and logistic impacts. Only about 10% of the boilers east of the Mississippi River, where the impact of acid rain is felt most, are subject to New Source Performance Standards.² Most of the remaining 90% are older units having a useful life of 10 to 30 years. An effective control technology for these boilers would result in significant reduction of national SO₂ and NO_x emissions. There is a need, therefore, for lower cost control technologies which can be retrofitted to this existing boiler population.

The EPA has been working on the following applicable technologies:

1. LIMB (Limestone Injection Multistage Burner) which is based on the injection of a dry sorbent into the boiler for direct capture of SO₂ in the flue gas, combined with the use of low-NO_x burners for reduction of NO_x emissions.
2. E-SO₂, which combines spray dryer technology with advanced electrostatic precipitator (ESP) technology to remove SO₂ and particulate matter in the modified ESP.
3. ADVACATE (ADVANCED siliCATE) which is based on in-duct injection of a highly reactive calcium sorbent for SO₂ control.
4. In-furnace reburning which stages fuel in boiler combustion zones to achieve substantial reduction in fuel-derived NO_x.

5. An advanced low-NO_x burner in which fuel and combustion air are slowly mixed, limiting NO_x formation in the flame.

This paper describes these program areas and provides an overview of objectives, approach, current status, and plans for each. In addition, it describes plans for a small-scale selective catalytic reduction (SCR) system.

SO₂ TECHNOLOGIES

LIMB

Building on attempts made in the early 1970s, EPA initiated a research and development program in 1981 to improve the LIMB process and bring the technology to a commercial scale. Current emphasis is on large-scale prototype testing and full-scale demonstrations with supporting research activities.

In the LIMB process, a sorbent is injected into the boiler at a location which provides the optimum time/temperature for reaction to remove 50-70% of the sulfur present. The NO_x is controlled by utilizing a specially designed burner in the boiler. Two major designs are being addressed: 1) wall-fired boilers, and 2) tangentially fired boilers. Each design comprises about 45% of the existing population, and there are significant differences between them with respect to their firing systems and resultant changes in combustion conditions. Commercial-scale wall-fired and tangentially fired demonstrations, and a large-scale prototype evaluation are currently underway.

The basic goals of the LIMB demonstrations are to extend technology development to full-scale applications on representative utility boilers. The successful retrofit of LIMB to an existing boiler is expected to demonstrate that:

1. SO₂ reduction of 50% or more and NO_x emissions of less than 0.5 lb/10⁶ Btu can be achieved at a fraction of the cost of add-on FGD systems.
2. Boiler reliability, operability, and steam production can be maintained at levels existing prior to LIMB retrofit.
3. Technical difficulties attributable to LIMB operation, such as additional slagging and fouling, changes in ash disposal requirements, and an increased particulate load, can be resolved in a cost-effective manner.

Each demonstration project consists of several distinct phases: a preliminary phase to develop the LIMB process design specifically for the host boiler, a construction and start-up phase, and an operating and evaluation phase.

The goals of the prototype activity are essentially the same. However, in contrast to the demonstrations, the tangentially fired prototype effort is not an evaluation of a single point design but an evaluation under different

design and operating conditions including several coals and sorbents. The two demonstration programs (wall-fired and T-fired) and the large-scale LIMB prototype program are discussed below.

Wall-Fired LIMB Demonstration¹

This demonstration is a 4-year project that includes design, installation, operation, and testing of a LIMB system at the 105 MWe, Unit 4 boiler at Ohio Edison's Edgewater Station in Lorain, OH. The primary fuel being used is an Ohio bituminous coal having a nominal sulfur content of 3%. EPA is sharing the cost of the project with the major participants: the State of Ohio, Ohio Edison, Babcock & Wilcox (B&W), and Consolidation Coal.

The process design was completed and the LIMB system installed at Edgewater in 1987. A short series of tests were conducted with the low-NO_x XCL burners in order to allow comparison with data obtained on the circular burners they had replaced in 1986. NO_x emissions with the XCL burners achieved the project goal of 0.5 lb/10⁶ Btu over the full operating range of the boiler. This performance represents approximately 40-50% reduction when compared to data on the circular burners. Further burner tests are planned after optimization of sorbent injection.

The 1987 operating period showed that LIMB could produce the desired SO₂ removal rates, but it also produced an ash with a high electrical resistivity which could not be effectively removed in the electrostatic precipitator (ESP). In order to maintain particulate emissions within opacity limitations, LIMB operation was limited to 3 to 8 hours per injection period: long-term continuous operation was not possible.

A series of short test runs were conducted over a 2 week period, and valuable operating experience and information were obtained. The first week was devoted to operation using a commercial, hydrated calcitic lime sorbent and the second to operation with a modified sorbent which had been shown to improve SO₂ removal in smaller scale tests. The modified sorbent was manufactured with the addition of small amounts of calcium lignosulfonate in the hydration step. A removal efficiency in the 55 to 60% range was obtained at a Ca/S stoichiometry of 2 with both sorbents; the project goal of 50% removal appears obtainable at a Ca/S ratio of 1.6.

Operation during the 1987 tests was characterized by steady degradation of the ESP, indicated by an increase in stack opacity. ESP current/voltage readings showed that the high resistivity ash was producing back corona in the ESP. The condition was so severe that all attempts to find an effective operating voltage were unsuccessful. One method of reducing LIMB ash resistivity and restoring ESP efficiency is to condition the flue gas by humidification. Since a flue gas humidifier was being added to the system for SO₂ removal, further attempts at operating the LIMB demonstration were discontinued until the humidifier was installed and operable.

Following completion of the humidifier installation in August 1988, the LIMB/humidifier system operation and testing has been resumed. During initial operation, modest humidification down to outlet temperatures of roughly 275°F has been sufficient to enable continuous ESP operation with no detrimental effects from LIMB ash. Long-term tests show that the initial SO₂ removal

rates observed in the 1987 tests can be maintained over longer periods. Efforts are underway to operate the humidifier at low outlet temperatures to obtain SO₂ removal in the humidifier and improve the overall efficiency of the LIMB/humidifier system.

As one of the nine projects selected under the U.S. Clean Coal Technology Program, the U.S. Department of Energy (DOE) has selected an extension to the LIMB wall-fired demonstration at Edgewater. This approximately 42-month program will provide a by-pass duct for EPA's humidification testing, an additional year of LIMB testing with up to 12 sorbent/coal combinations which include humidification and simulated sorbent recycle, and an evaluation of CONOCO's technology.

Tangentially Fired (T-Fired) LIMB Demonstration'

EPA initiated demonstration of LIMB technology on a tangentially fired utility boiler on June 12, 1987, with the signing of a contract with Combustion Engineering as the prime contractor. Over 50% of the program value is being provided by industrial partners including Combustion Engineering, Virginia Power Company, and Radian Corporation. Other industrial partners include Stone and Webster Engineering Corporation and C-E Lummus. The Government share of the funding is being provided by EPA and DOE.

In addition to the LIMB demonstration objective previously stated, the program will also evaluate the SO₂ removal enhancements achievable with flue gas humidification and sorbent reactivation and recycle.

The demonstration site is the 180 MWe coal-fired Yorktown Unit 2 of Virginia Power Co. in Yorktown, VA. An intermediate sulfur content coal (about 2%) will be fired during the demonstration program. The T-fired demonstration is expected to span a total period of about 5 years, of which about 1 year will be dedicated to the LIMB performance evaluation.

The demonstration program field testing has been supported by mathematical modeling and pilot-scale testing at C-E Kreisinger Development Laboratory (KDL). These pilot-scale investigations included aerodynamic flow modeling and testing on a 5 MWe Boiler Simulation Facility (BSF). The BSF was built for a prior program to develop criteria for the location and method of sorbent injection into tangentially fired coal-burning utility boilers. It models the time/temperature history, heat release rate, heat absorption, and aerodynamic characteristics of a large utility boiler.

It is estimated that equipment installation, construction, shakedown, and debugging will be completed by late July 1990, at which time performance evaluation will be initiated and, including long-term operation, will be complete by late 1991. A final report is anticipated by late 1992.

Large-Scale LIMB Prototype Evaluation'

The EPA and the Electric Power Research Institute (EPRI) are co-sponsoring and co-managing a 4-year program to evaluate sorbent injection technology on Richmond Power and Light's (RP&L's) Whitewater Valley Generating Station, Unit 2, in Richmond, IN. This unit is a 61 MW tangentially fired utility boiler constructed in 1973 (pre-NSPS) and was retrofitted in 1980 with

the low-NO_x concentric firing system (12 burners). This unit is equipped with a Lodge Cottrell cold-side precipitator (SCA - 198) and a Ljungstrom air heater.

Objectives of the 3-phase program are:

1. To provide a utility-scale boiler which can be utilized to support R&D demonstration and testing programs.
2. To provide a testing program to measure the relationship between SO₂ capture performance and different injection schemes using various coals, sorbents, and loads.
3. To evaluate the impact of LIMB technology on boiler and ESP performance and operability by testing over a wide range of conditions representative of tangentially fired utility boilers in the U.S.
4. To provide a data base which can be used directly by the utility industry to apply these technologies to meet projected emission reduction requirements at minimum total cost.

Each phase will focus on one specific injection technology and will consist of periods for parametric testing, optimization testing, and long-term operational testing totaling about 4 months.

Phase I, the initial field evaluation, will involve upper furnace injection of calcium based sorbents with humidification upstream of the ESP to enhance ESP performance. Contingent on results and availability of resources, the second and third field evaluations (Phases II and III) will be activated based on the status of the technology at that time.

Due to sorbent handling problems during the start-up period, satisfactory long-term steady-state operation of the sorbent injection system was not achieved. The humidification and sorbent injection systems were operational for periods of 4-6 hours under various short-term operating conditions. Under these short-term conditions, humidification was shown to enhance ESP performance during sorbent injection. Specific results and observations of these activities are reported in Reference 3.

As a result of the sorbent handling difficulties, start-up activities were terminated in December 1987; and an effort was initiated to analyze, redesign, and modify the material handling system. An industry survey was conducted to evaluate other experiences of the handling, transport, and rate control of fine particle materials, and a workshop was held in February 1988 to focus on material handling issues centered around the design and operation of equipment for the feed rate control and transport of the finely powered sorbents used in the LIMB process. The workshop also discussed issues relative to LIMB's impact on ESP performance. Participants included all major LIMB contractors, EPRI, and a Canadian utility, Saskatchewan Power.

Participants openly shared prototype and large-scale experience focusing on these two topics followed by discussion of various technical approaches.

Installation of the redesigned material handling system was completed in August 1988 and start-up was initiated. Parametric testing to evaluate multiple sorbents, coals, and sorbent injection schemes at various operating loads of the furnace started in September 1988 and was completed 3 months later. Parametric test results are being analyzed.

E-SO,³

E-SO, is a retrofit process which combines ESP technology for collecting particles and spray dryer technology for SO₂ removal in a single unit, for coal-fired boilers. The process makes use of a modified existing ESP with an auxiliary system for preparation and injection of a sorbent slurry into the ESP.

In the E-SO, concept, the front end of an existing ESP is converted to a spray chamber where contact is made between gaseous SO₂ and wetted lime particles. Water is also evaporated in this converted section of the ESP so that the reaction product, excess lime, and fly ash which enter the remainder of the ESP are sufficiently dry for efficient ESP operation. The electrical components of the remainder of the ESP are left intact so that it operates as a particle collector. To provide this contacting chamber with sufficient space to allow a finite drying time of 1 second or longer, the ESP will most likely lose 25-30% of its collector plate surface. At the same time, the particulate load will increase by a factor of three or more. This particulate, a large fraction of which is calcium based, has high electrical resistivity. The sorbent reaction with SO₂ will eliminate sulfur trioxide (SO₃) effects that would lower this resistivity. On the other hand, lowering of the gas temperature by the water spray will compensate for resistivity increases due to ash composition. Advanced ESP technology is available to aid in maintaining good performance in particulate collection. Cold-pipe precharging and large diameter electrodes, for example, can be introduced in retrofitting ESPs to compensate for smaller collector surface or changes in resistivity characteristics.

The current program is sponsored by EPA and the Ohio Coal Development Office (OCDO) with cost-sharing by Babcock & Wilcox (B&W), the prime contractor, and Ohio Edison, the host site utility company. The program consists of laboratory and pilot R&D performed by EPA, B&W, and Southern Research Institute directed toward the objective of demonstrating the feasibility of E-SO, technology on a 5 MWe equivalent utility boiler flue gas slipstream at Ohio Edison's R. E. Burger Plant in Dilles Bottom, OH. Successful application of this technology on a 5 MWe system is expected to demonstrate that:

1. A minimum of 50% SO₂ can be removed from combustion of coals with sulfur contents typical of fuels burned in Ohio at economical stoichiometries.

2. Operation in particulate compliance for existing units can be achieved with particulate emissions of less than 0.1 lb of particulates/10⁶ Btu of coal fired.
3. The E-SO₂ process will cost \$100/kW less than wet FGD.
4. ESP reliability and operability can be maintained at the levels prior to the retrofit of the E-SO₂ system.
5. Technical difficulties such as changes in ash disposal requirements can be resolved in a cost-effective manner.

Experimental effort has focused on addressing the fundamental issues of the E-SO₂ concept: 1) the feasibility of removing substantial SO₂ from the rapidly moving gas in contact with slurry droplets and drying the droplets before the gas enters the first electrical section of the ESP, and 2) maintenance of an acceptable level of ESP performance with a smaller collector area and an increased particulate loading.

A number of small pilot tests were performed at EPA to evaluate these issues. SO₂ removal improved as approach to saturation temperature decreased and stoichiometric ratio increased.

At extremely low approach temperatures, good removal is obtained at very low ratios. However, moisture in the ESP ash limits the lowest approach temperature to 28-30°F. Stoichiometric ratios of 1.3 to 1.4 produced a removal of 50% or more at a 30°F approach to saturation.

With respect to ESP performance, efficiencies of 99% and above were obtained even in the face of a fourfold increase in particulate loading and a 50% reduction in ESP SCA. The high efficiency is attributable to several factors taken together: lower ash resistivity, particle agglomeration, and the use of a cold-pipe precharger to enhance collection of low resistivity dust.

In summary, basic concepts of the E-SO₂ process have been verified at small pilot-scale with a simulated flue gas. Removal of 50% or more of the SO₂ emitted from a boiler burning a 2.5-3% sulfur coal appears to be a reasonable goal. At the level of lime usage required and the observed performance of the shortened EPA in-house ESP, experimental evidence appears to verify ESP performance. Installation of the 15,000 acfm pilot ESP at the Burger Plant was initiated in May 1988 and checkout and shakedown testing was completed earlier this year. Following configuration testing for baselining, etc., parametric and operability testing will be performed and a final test report is expected about November 1989.

ADVACATE Process^{6,7}

The ADVANCED silicate process was co-developed by the University of Texas, EPA, and Acurex Corporation. In this process, silica and calcium sources are slurried together at elevated temperatures to produce a unique silicate material which has the following properties:

- (1) high reactivity toward SO₂,
- (2) low crystallinity
- (3) ability to carry significant moisture and be free-flowing

With these properties the silica sorbent may be used in a low capital-cost duct injection process and avoid all the pitfalls of duct injection; e.g., low reliability due to use of spray nozzles, irreversible duct deposits, and low calcium utilization.

There are three ADVACATE process configurations for coal-fired boilers: one for ESP retrofit, another for a new system with fabric filter dust collection, and a third in combination with LIMB. Lime is the most likely source of calcium but, where alkalinity in coal ash is sufficient as in many Western U.S. coals, no imported calcium is necessary. The most economical silica source is fly ash. The only equipment added in a retrofit scheme is the hydrator vessel, a feed hopper, and a dust injection system into existing ductwork.

Pilot-plant evaluation at EPA's Research Triangle Park facilities have typically shown sorbent utilizations of 50% in-duct and 90% with fabric filter collector.

EPA recently entered into a cooperative research agreement with Flakt, Inc., specifically for commercialization of ADVACATE. With proprietary Flakt duct injection technology, over 80% calcium utilization has been achieved in-duct within a 1 second residence period, and over 95% utilization has been observed with the fabric filter collector. These utilizations are contrasted with currently reported in-duct utilizations of 25-33% (50% SO₂ removal at Ca/S of 1.5-2.0) by in-duct sorbent injection processes under development.

In addition to the high SO₂ removal calcium utilization and ease of retrofit, other advantages observed in pilot and field work include: (1) lower pressure losses in fabric filtration, (2) no in-duct deposits, and (3) no deterioration of ESP performance despite significantly increased duct loading.

Currently Flakt is developing plans for a full-scale ESP retrofit at a site to be determined. Meanwhile EPA is evaluating ADVACATE on pilot municipal incinerator applications and modifying the sorbent for enhanced NO_x capture in-duct. Also, limited evaluation of a combined LIMB-ADVACATE process is currently underway on a slipstream at the Edgewater LIMB demonstration site.

NO. TECHNOLOGIES

Combustion Modifications¹

In the late 1970s and early 1980s, EPA conducted extensive field evaluations of combustion modification NO_x controls. Although many programs are no longer active, some brief summary of experience is in order. The simplest retrofit NO_x technique involves minimizing oxygen or excess air to burners. This low excess air (LEA) technique reduced emissions of NO_x by 20%. LEA may be enhanced by operating rows of burners at very low excess air and providing additional air in the upper boiler regions, called air staging or staged combustion air (SCA). EPA field tests of 22 pulverized coal boilers retrofitted with LEA/SCA resulted in NO_x reductions ranging from 12 to 62% and averaging 37% NO_x reduction. Capital costs averaged \$2/kW in 1980.

First and Second Generation Burner Technology

First generation low-NO_x burners reduced NO_x by delaying the mixing of fuel and combustion air, thereby limiting the availability of free oxygen in the initial burning process. First generation burner technology has already been incorporated in commercial application and was the basis for reducing the New Source Performance Standard (NSPS) for NO_x in 1979 for coal-fired utility boilers. Capital costs of \$5/kW were estimated at that time.

EPA continued low-NO_x burner R&D into the 1980s with the development of second generation burners. The program emphasis was on retrofit and new applications with a NO_x goal of 0.5 lb/10⁶ Btu or less, with no adverse impact on other pollutants (CO and HC), and retaining or improving boiler efficiency, operability, and reliability. Required burner characteristics also included stable flames, acceptable flame length and shape, minimal slagging, wall erosion and corrosion, and acceptable pressure drop. Two such concepts developed under EPA sponsorship were the distributed mixing burner (DMB) for wall-fired boilers, and a concept called "rich fireball" for application to tangentially fired boilers. Experimental tests of these burner concepts were conducted in highly versatile combustion test systems with firing rates ranging from 1 to 120 x 10⁶ Btu/hr. For the DMB concept, NO_x emissions fell within the range of 0.3 to 0.5 lb/10⁶ Btu. The "rich fireball" concept showed NO_x emissions in the range of 0.3 to 0.4 lb/10⁶ Btu.

These encouraging results provided the basis for taking these burner concepts to full-scale demonstration. The DMB approach was installed on a 22 MWe unit at Western Illinois Power Cooperative (WIPCO) as a four-burner array. NO_x emissions over a wide range of boiler operating conditions fell within the range of 0.3 to 0.5 lb/10⁶ Btu, with long-term operation typically being at 0.5 lb/10⁶ Btu. The "rich fireball" approach, later termed "Low-NO_x Concentric Firing System" (LNCFS) was demonstrated on a 20-burner, tangentially fired unit at Utah Power and Light Co. (UP&L). NO_x emissions over a range of boiler operating conditions ranged from less than 0.3 to 0.4 lb/10⁶ Btu. The average of 4 long-term (30-day) continuous emissions tests was 0.41 lb/10⁶ Btu. This basic burner design will be used at EPA's tangentially fired LIMB demonstration site at Virginia Power Co. An evolution of the B&W first generation low-NO_x burner, referred to by its manufacturer as the "XCL burner," is currently in service in a 12-burner array at Ohio Edison as part of the demonstration of LIMB technology for wall-fired boilers. No

long-term data are yet available, but NO_x levels in the range of 0.4 to 0.5 lb/10⁶ Btu are being routinely achieved.

Results of these commercial scale field tests are shown in Table 1.

TABLE 1. SUMMARY OF RETROFIT EXPERIENCE
(FULL LOAD NO_x EMISSIONS, lb/10⁶ Btu)

<u>Host Site</u>	<u>MWe</u>	<u>Baseline with Original Burner</u>	<u>Controlled with Retrofit Burner</u>	<u>NO_x Reduct. %</u>
WIPCO	22	0.95	0.51(DMB)	46
Ohio Ed.	105	0.89	0.46(XCL)	44
UP&L	400	0.62	0.35(LNCFS)	44

Future plans for selected low-NO_x burners like the XCL and LNCFS include longer term verification of emissions and combustion performance. Where possible this will be augmented with stringent 30-day continuous emissions monitoring tests. Documentation of emissions, operability, and costs will be provided as output from these studies.

Reburning

Another technology available to achieve significant reductions (up to 60%) in NO_x from coal-fired boilers is a process known as reburning. It is believed to be the only NO_x control technology which can be retrofitted to cyclone boilers, which have the highest NO_x emissions of the boilers currently in use. The process can also be used on wall-fired and tangentially fired dry- or wet-bottom boilers in conjunction with burner modifications to achieve NO_x reductions well in excess of 60%.

The reburning process diverts up to about 20% of the fuel energy from the primary burners to the fuel-rich post-flame gases known as the reburn zone. Stoichiometry in the reburn zone is 0.9 - 0.95, and the desired residence time is 0.5 - 0.7 seconds. Reburn fuel, which can be coal, oil, or gas, is injected at as high a temperature as possible to maximize fuel use, yet not cause excessive NO_x formation. The reburn fuel combustion is completed in the burnout zone above the reburn zone, when sufficient air is injected to complete carbon burnout. Burnout air is injected at as low a temperature as possible to prevent the formation of additional NO_x. The reducing environment in the reburn zone prevents the formation of some NO_x that would have been formed. This environment also produces an abundance of amines and hydrocarbon radicals which directly or indirectly convert NO_x to molecular nitrogen.

EPA, in conjunction with the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI), and the Ohio Coal Development Office (OCDO), is demonstrating gas reburning on a 108 MWe coal-fired cyclone boiler at Ohio Edison's Niles plant. The reburn system will be fabricated and installed by the end of 1989. Parametric and optimization testing will be completed

followed by long-term testing to begin in Spring 1990. EPA is also involved in a cooperative coal reburning demonstration on a 300 MWe wall-fired wet-bottom boiler at Ladyzhinskaya, Ladyzhin, U.S.S.R.

In addition to the obvious considerations of NO_x reduction and safe operation using natural gas, the long-term testing program will focus on the changes in heat adsorption rates in various parts of the boiler. The objective is to achieve an optimal mode of operation which minimizes the energy penalty associated with the process. Another focal point will be the monitoring of tube wastage rates. It is known that, under some circumstances, reducing environments can be conducive to enhanced boiler tube wastage. It is believed that with careful process control, however, this phenomenon can be almost wholly avoided.

Selective Catalytic Reduction

While decidedly not a low-cost retrofit technology, selective catalytic reduction (SCR) has been commercialized in Japan and Europe and still represents the highest potential NO_x reduction technology available for retrofit. With recent decisions by some states to require SCR technology on certain new cogeneration systems and the inclusion of SCR in Clean Coal II awards, EPA is concerned that fundamental knowledge of SCR, particularly with respect to high sulfur coal applications, is necessary to ensure successful commercialization in the U.S. AEERL has recently begun construction of a bench-scale SCR system in order to evaluate many concerns, including:

- ° Coal and flue gas constituents which affect catalyst performance; i.e., erosion, aging, poisoning, and overall loss of performance
- ° Secondary impacts (NH₃, N₂O emissions)

The goal is to establish a system which can conduct "rapid aging" studies to determine quickly the long term performance and costs of specific SCR catalysts for specific flue gas sources, as well as investigate secondary emission impacts of these applications. Further, such new concepts as molecular sieves need comparative evaluation to SCR. In short, AEERL intends to set up a system which can function as a basic SCR evaluation laboratory for potential SCR users, in particular an apparatus which can be quickly and inexpensively modified to optimize SCR operations on a larger scale.

Plans are to begin operation of this system next month (May 1989) at AEERL's Research Triangle Park, NC, facilities.

REFERENCES

1. Nolan, P. S., R. V. Hendriks, and N. Kresovich, "Operation of the LIMB/Humidifier Demonstration at Edgewater." Presented at the First Combined FGD and Dry SO₂ Control Technology Symposium, St. Louis, MO (October 1988).
2. Stern, R. D., "An Overview of EPA's Program for Retrofit Sorbent Injection Technologies". Presented at the APCA International Specialty Conference on Environmental Challenges in Energy Utilization During the 90's, Cleveland, OH (October 1988).

3. Gogineni, M. R., J. P. Clark, J. L. Marion, R. W. Koucky, D. K. Anderson, A. F. Kwasnik, E. Gootzait, D. G. Lachapelle, and S. L. Rakes, "Development and Demonstration of Sorbent Injection for SO₂ Control on Tangentially Coal-Fired Boilers." Presented at First Combined FGD and Dry SO₂ Control Technology Symposium, St. Louis, MO (October 1988).
4. England, G. C., B. A. Folsom, R. Payne, T. M. Sommer, M. W. McElroy, P. Jeff Chappell, and I. A. Huffman, "Prototype Evaluation of Sorbent Injection with Humidification." Presented at First Combined FGD and Dry SO₂ Control Technology Symposium, St. Louis, MO (October 1988).
5. Hovis, L. S., R. E. Valentine, J. L. DuBard, and J. C. S. Chang, "E-SO₂ System for Combined Particulate and SO₂ Control." Presented at the Seventh Symposium on the Transfer and Utilization of Particulate Control Technology, Nashville, TN (March 1988).
6. Jozewicz, W., C. Jorgensen, J. C. S. Chang, C. B. Sedman, and T. G. Brna, "Development and Pilot Plant Evaluation of Silica-Enhanced Lime Sorbents for Dry Flue Gas Desulfurization," JAPCA 38:796-805 (1988).
7. Jozewicz, W., J. C. S. Chang, T. G. Brna, and C. B. Sedman, "Reactivation of Solids from Furnace Injection of Limestone for SO₂ Control," Environ Sci. Technol., 21:664 (1987).
8. Ponder, W. H., "Technologies for Controlling Pollutants from Coal Combustion." Presented at the Clean Coal Technology Conference, Arlington, VA (October 1985).

*Readers more familiar with the metric system
may use the following conversion factors:

<u>From</u>	<u>To</u>	<u>Multiply By</u>
acfm	m ³ /min	0.020832
lb/10 ⁶ Btu	ng/J	429.94
°F	°C	°C=5/9 (°F-32)
Btu/hr	watts (thermal)	0.293

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